Cloud computing for energy management in smart grid – anapplication survey

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Abstract. The smart grid is the emerging energy system wherein the application of informationtechnology, tools and techniques that make the grid run more efficiently. It possesses demandresponse capacity to help balance electrical consumption with supply. The challenges andopportunities of emerging and future smart grids can be addressed by cloud computing. Tofocus on these requirements, we provide an in-depth survey on different cloud computingapplicationsforenergymanagementinthesmartgridarchitecture.Inthissurvey,wepresentan outline of the current state of research on smart grid development. We also propose a modelofcloudbasedeconomicpowerdispatchfor smartgrid.

1. Introduction

Electrical power has become an indispensable part of modern day life. Hebra [1] and NIST [2] styledtoday'selectricpowersystemasamultifacetedsystemofpowergeneration,transmission,anddistribution. With the global economy more reliant on sustainable development of energy, a series ofproblems,suchasenergyshortage, electricityblackout andglobalwarmingaregainingattention.ABB [3]pointedoutthattherearetenaciouseconomicaswellasenvironmentalurgingsfortherefurbishment of the conventional power systems, and its replacement with a Smart Electrical PowerGrid or simply Smart Grid. A smart grid is an electricity network that uses digital and other advancedtechnologies to monitor and manage the transport of electricity from all generation sources to meet thevaryingelectricitydemandsof end-users [4].

Energy demand from the users changes dynamically in different time-periods. The existing powergrids need optimal balancing of electricity demand and supply between the customers and the utilityproviders.Toaddresstheserequirementsinsmartgrid,theenergymanagementsystems(EMS)suchasbuildingenergymanagement(BEMS),demandsidemanagement(DSM)andhomeenergymanagement (HEM) are integrated. A smart grid allows various renewable energy sources to have anefficientmanagementofsupplyanddemand.Thespecialcharacteristicofasmartgridisitsheterogeneous architecture, which includes Demand Response (DR), distributed generation, resourcescheduling,and real-time pricingmodel.

In a smart grid environment, multiple devices are implemented such as smart meters, substations,micro-grids,homeappliances,sensornodes,andcommunicationnetworkdevices.Smartmeters, deployed in the distribution sites, generate massive data for real-time communication with the utilities.To handlesuchmassivedataefficiently andeffectively, smartgrid relieson theutilization andintegrationofadvancedinformationtechnologies[5].Oneoftheimportanttrendsintoday'sinformation management is outsourcing tasks to cloud computing, which has been regarded as thenext-generationcomputingand storage paradigm[6].

1.1. Contribution

In this paper, we provide a methodical summary of assimilating cloud computing applications forenergymanagementinsmartgrids.Communicationnetwork playsanimportant roleforreliableenergy management as smart grid is the combination of electrical and communication network. Cloudcomputing techniques proposed in the existing literature for energy management in smart gridarediscussed briefly. A model of power dispatching in smart grid with cloud is described. In short, ourobjectivein thispaper is tooffer the following:

- Acomprehensiveoverviewofsmartgridandcloudcomputingintermsofenergymanagement.
- Aclear concept ofcloudcomputingapplicationsinsmart grid.
- Ahighlightoncosteffectivecloudbasedpowerdispatchinginsmartgrid.

The rest of the paper is organized as follows. In Section 2 and Section 3, we give a comprehensiveoverview of smart grid and cloud computing. We briefly describe the cloud computing applications inthe context of energy management in smart grid in Section 4. Cost effective cloud based powerdispatchinginsmartgridispresentedinSection5.Finally,a conclusionisprovidedinSection6.

2. SmartGrid

Smart Grid monitors power use, adapts consumption to match power costs and system load, andintegrates new kinds of renewable energy sources with conventional power generating systems. Itassociates every distributed electricity producer (independent power producer) in the energy marketfrom conventional thermal, hydroelectric and atomic power plants to new kinds of renewable energysystems with each electricity consumer, from industries to residences, and to every load plugged intothe electric network. The digitally controlled, self-monitoring and self-healing Smart Grid providestwo-way communication for energy production, transmission and distribution, control and monitoring,supply and demand balancing, etc. with more customer choices. According to NIST [2] “a modernizedgridthatenablesbidirectionalflowsofenergyandusestwo-waycommunicationandcontrolcapabilities that will lead to an array of new functionalities and applications”. The NIST Smart GridFramework is shown in figure 1, which shows the involved domains, the actors in a particular domainand interaction between the actors from other domains. Each domain encompasses Smart Grid actorsand applications. Actors make decisions and information exchange that are required for performingapplications. Actors include devices (e.g. smart meters, solar energy generators, and control systems),programs, systems, and stakeholders. Tasks performed by one or more actors within a domain arecalled applications (home automation, and energy management).An important characteristic of a smartgrid is controlling electricity consumption at the customers’ ends [7]. To achieve this metering andmonitoring, a few components are incorporated in the smart grid architecture. These key componentsofsmartgridare discussedas under:

2.1. AdvancedMeteringInfrastructure

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communicationsnetworks, and data management systems that enables two-way communication between utilities andcustomers [8].Smart metersat thecustomersite are theelectrical meters that record real-timereadingsi.e.consumptionofelectricalenergy,andvoltagequalitythatareanticipatedtoberead periodically in shorter intervals (range from minutes to milliseconds). In general, AMI support datacommunicationarchitecturebyincludingsoftwareandelectronic/digital hardware.

2.2. AdvancedMeteringInfrastructure

Health and performance monitoring of transformers, feeders, capacitors, circuit breakers, conditionmonitoring of lines (e.g. PLCs), fault detection and replacement of assets can be performed effectivelyand efficiently by the analysis of data sensed at regular intervals by the intelligent monitoring system.With the development of sensors that utilize low-cost, ultra-low-power processors and communicationlinks to transmit data, a new regime of sensors known as the smart sensors have recently come intoexistence[9].Extensiveresearchinthewirelesstechnologyreducingthesignalnoise,powerrequirement and enhancing the range has made the wireless technology a potential for integration withsmartsensorstocarrycommunicationwithutilities.Developmentofeffectivenetworktopologiessuch as multi-hop link networks and efficient wireless signal routing algorithms have further improvedthe range and reduced power consumption; hence made the advent of protocols like ZigBee Pro [10].Some examples of sensors present in the commercial domain are Tollgrade's Lighthouse MV sensors,USi's Power Donut, ABBs Grid Sync, Grid Sense's Line IQ, Sentient monitor, and Grid Sentry's Linesentry. The size, cost and weight restrictions of the sensors mentioned above have posed the hindrancetotheir wide acceptance.

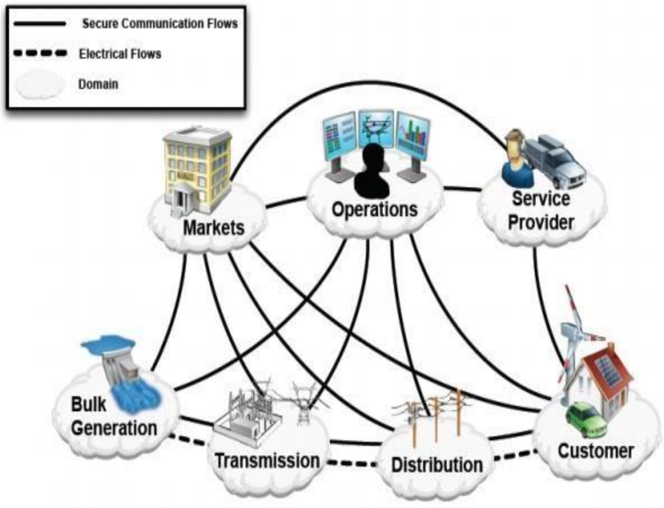

Figure1.NISTSmart GridFramework**.**

3. CloudComputing

Cloud computing - amodel that enables convenient, ubiquitous, on-demand access to a pool ofcomputing resources (e.g. servers, networks, applications, storage, and services) that are configurable.With minimal management effort, resources can be provisioned and released seamlessly [11]. NIST'svisual model of cloud computing definition is shown in figure 2. It delivers infrastructure, platform,and software to customers as subscription-based services in a pay-as-you-go model. The advantages,essentialcharacteristics, ofusinga cloud computingmodelareasfollows[12-14]

- On-demandself-service:Aconsumercanindividuallyprovisioncomputingcapabilitiesasneededautomaticallywithout requiringhumaninteractionwitheach serviceprovider.
- Broad networkaccess:Capabilitiesareavailable overthenetwork.Itcanbe accessedthroughstandardmechanisms,to beused byheterogeneousthinorthickclient platforms.
- Resource pooling: A multi-tenant model is used to serve multiple consumers from a pool ofcomputing resources. The customer has no control over the exact location of the providedresources.
- Rapid elasticity: Cloud computing supports elastic nature of storage and memory devices. Itcanexpand and reduceitself accordingto thedemand fromthe users,as needed.
- Measuredservice:Cloudcomputingoffersmeteringinfrastructuretocustomers.Costoptimization mechanisms are offered to users, enabling them to provision and pay for theirconsumedresources only.

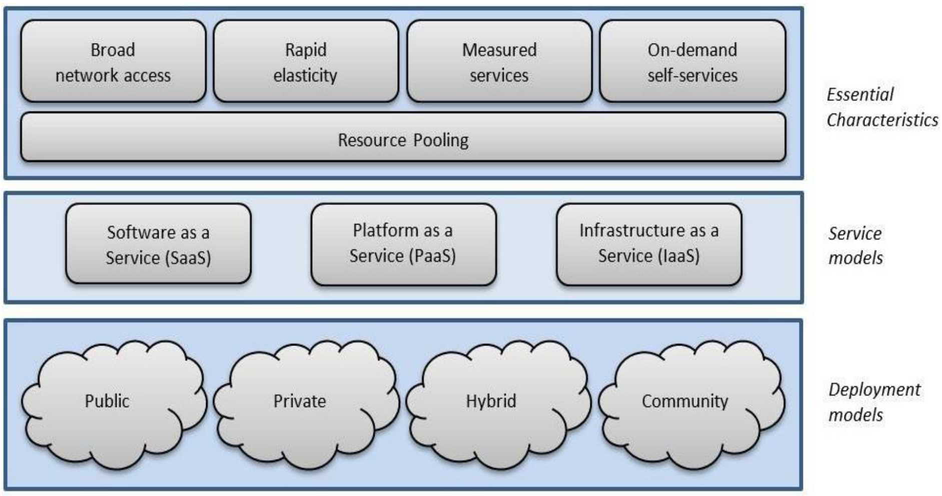

Figure2.NIST Visualmodelofcloudcomputingdefinition.

Virtualization technology can be used in cloud computing that can take a variety of different typesofcomputingresourcesasabstractedservicestousers.ThesecloudservicesaredividedintoInfrastructure-as-a-Service(IaaS),Platform-as-a-Service(PaaS)andSoftware-as-a-Service(SaaS).

- Infrastructure-as-a-Service: IaaS provides scalable infrastructure e.g. servers, network devices,and storage disks to consumers as services on demand. The access to the cloud is providedthrough various user interfaces, such as web service application programming interface (API),command-line interfaces (CLI) and graphical user interfaces (GUI) which provide differentlevel of abstraction. The consumer has control over operating systems, storage, and deployedapplicationsbut theyarenot requiredtomanage or control the cloudinfrastructure.
- Platform-as-a-Service: PaaS provides a platform where users or customers can create and runtheir applications or programs. The users can build and deliver Web-applications withoutdownloadingandinstallingrequiredsoftware,asPaaSservicecompletestherequirements.Itisresponsiblefortheruntimeexecutionofusers'giventask.Themostimportantcustomersforthis layerare the developers.
- Software-as-a-Service:SaaS is responsible for delivering various kinds of applications plusthe interfaces for the end users. This feature of cloud computing is accessible through Web-browsers.TheSaaSprovidesthemodelingofsoftwaredeploymentwhereuserscanruntheir applicationswithoutinstallingsoftwareonhis/herowncomputer.However,thisserviceislimitedtotheusers,i.e., onlyexistingset of servicesisavailableto thecustomers.

According to the deployment model, a cloud can be classified as public cloud, private cloud,communitycloud, and hybrid cloud[11].

- Private cloud: The Private cloud is a virtual environment deployed within an organization thatis restricted to users within the company and usually resides behind the corporate firewall. It issuitedforsecuredconfidentialinformationandcoresystems.Itmayexistonoroffpremises.
- Community cloud: The Community cloud is similar to a Private cloud. It is provisioned to agroup of organizations who have similar type of requirements with additional features. It mayexist on or off premises.
- Public cloud: The Public cloud is a virtual environment that is publically available for anyconsumer to purchase computing resources, usually on a pay per use basis, via an easy to usewebportal. Itexists onthepremisesof the cloudprovider.
- Hybrid cloud: The combination of the Public and Private cloud whereby specific resources areusedin PublicCloudwhileothers are usedin Private Cloud.

4. CloudApplicationsforEnergyManagement

Energy management is the process of monitoring, controlling, and conserving energy [15]. In smartgrid, energy management is a major concern [16]. It is needed for resource conservation, climateprotection and cost saving without compromising work processes by optimally coordinating severalenergysources.BEMS(BuildingEnergyManagementSystem)andHEMS(HomeEnergyManagement System),dynamicpricing,andloadshiftingaredifferentapplicationsthatareimplementedbyresearchers inthe pasttoaddressenergymanagement.

4.1. ProblemswithExistingApproacheswithoutcloud

Demand Response (DR) refers to "changes in electric usage by end-use customers from their normalconsumption patterns in response to changes in the price of electricity overtime, or to incentivepayments designed to induce lower electricity use at times of high wholesale market prices or whensystem reliability is jeopardized" [17, 18]. DR is achieved through the application of a variety of DRresource types, including distributed generation, dispatchable load, storage and other resources thatmay contribute to modify the power supplied by the main grid [19]. In the conventional smart gridarchitecture (without cloud), several problems, as detailed below, are addressed by researchers [12, 13,20, 21].

- Master-Slavearchitected(withoutclouds)couldcauseCyber-attacks(DistributedDenialof-Service(DDoS)).
- Any failure in Master-Slave architecture could lead to a system failure, which does not exist incloudcomputing.
- Canserveforlimitednumber ofusers(customers)duetolimitedserver capacity.
- Servingofsuchlargenumberofthecustomerwillbechallengingbecauseoflimitedmemoryand storage.
- Management,aswellasstabilityissues,will berequired.

4.2. SolutionConceptwithCloudApplications

For many years, researchers proposed several solution concepts for demand response and micro-gridmanagement [12-14, 20, 22-39].

Kim et al. [12] proposed the concept of Cloud-Based Demand Response (CDR) for fast responsetimes in large scale deployment. In the concept of CDR, the Energy Management System (EMS) andsmartmeterswillbetheslaveswhilemasterwillbetheutility.Thedata-centriccommunication, publisher/subscriberwill beusedbytheCDR,wherebytwocloud-baseddemandmodelsaresuggested (a)data-centric communication and (b) topic-based group communication ratherthantypicalIP-centriccommunication.Overheadproblems,suchasimplementationcost,andtheselectionofappropriate strategy, exists in the demand response model [12] that occurs in the private cloud whenthesize ofthenetworkis small[7].

Ming Chen et al. [22] analyzed the necessity and feasibility of cloud computing technology inpower dispatching and presented the Deployment Method of power dispatching automation systembased on cloud computing. Easy standardization of power dispatching technique; rapid delivery ofadvanced functions; and significant improvement reliability of IT infrastructures can be achieved bymeans of cloud computing technology. It reduces administrative costs, and it solves the contradictionbetweenhierarchical managementand"integratedconstruction"inenergysector[22].

ZHANG Liang [23] proposed the concept of cloud dispatching, a kind of cloud computing-basedoverall framework of intelligent dispatching center. The cloud computing-based layered architectureincludesPhysicalResourceLayer- physicalhardware,platform resourcesandapplicationsystemssuch as SCADA, EMS, TMR, WARMS,Virtual Resource Layer - map physical resources in varioustypes into virtual resources,Cloud Service layer - packages virtual resources into services, that areposted to the clouds, Cloud Management Layer- provides integrated management of cloud servicesfor users, and Cloud Access Layer - the way user access cloud dispatching. It integrates the existingresources demands among various dispatching centers, reduces the system construction and expansioncostandimproves overalldispatchingbusiness ability.

The smart grid infrastructure needs to be deployed globally. In order to balance the real-timedemand and supply curves, rapid integration and analyzation of information that streams from multiplesmartmeterssimultaneouslyisrequiredthatnecessitatesthescalablesoftwareplatform.Yangetal. [13] proposed that cloud platforms are well suited to support huge data and computationally-intensive,always-on applications. To build a software infrastructure to support such dynamic and always-onapplications,scalablerequirementsofresourcesareofferedbythecloudapplications.Intheseenvironments, cloud platforms serve as essential components due to the various benefits they offer, asmentionedbelow:

- Cloudactselasticallytoavoidcostlycapital investment bytheutilityduringthepeakhours.
- Customerscanbebenefitedfromthereal-timeinformationbysharingthereal-timeenergyusageand pricinginformation.
- Somedatacanbesharedwithathirdpartybyusingcloudservices,aftermeetingthedataprivacypoliciesf ordevelopingintelligentapplicationstocustomizeconsumerneeds.

In order to take decisions at different instances, implementation of specialized data abstraction fordatastreamsgeneratedfromthedifferentcomponentsisrequiredforreal-timemonitoring.Ontheother hand, third-party vendors are allowed to participate in such real-time monitoring system thatnecessitatesdefiningan effectiveprivacypolicyasasecuritymechanism.

Virtualization is one of the most efficient techniques for cost reduction, resource optimization, andserver management [20]. Cloud computing can be implemented in the form of different strategies ofthemicro-grids.RajeevandAshok[20]proposed aframeworkforintegratingcloudcomputingapplications for microgrid management in the form of different modules such as infrastructure, powermanagement,andservice.Theinfrastructureandpowermanagementmodulesareusedfortaskscheduling andmicro-gridpowermanagementrespectively.Thedifferent operatorspublish theirservicedescriptionusingtheservicemodule.Withtheimplementationofcloudcomputing,theexternal computing devices can be integrated with the internal ones. Thus, the number of supportedcustomers increases as suggested by Rajeev and Ashok [20]. In such a manner, integrating virtualenergy sources with the existing energy storage devices and the energy exchange mechanism can beachievedamongthe micro-grids to meettheenergyrequirements fromconsumers.

Dynamic pricing implementation can be used to address energy management. Xuan Li and Lo [14]proposed two smart grid related issues: (a) peak demand and (b) dynamic pricing. Requests fromcustomers, which are to be executed, based on the priority, available resources, and other applicableconstraints, are scheduled with the integration of cloud. During peak hours, the messages from smartmeters are more than those in the nonpeak hours [14]. In such a scenario, incoming jobs from users arescheduledaccordingtotheirpriority,availableresources,andapplicableconstraints.Withtheintegration of dynamic bandwidth allotment mechanism using cloud application, these issues can beaddressed conveniently. During the peak-hour, the allotted bandwidth is higher than that in the non-peakhour,in ordertoservealltheincomingjobssimultaneously.

Cloud-based services are used for communication and management schemes in the smart grid by Jiet al. [24], while providing the facility of power monitoring and early-warning system as well.In sucha scenario, the real-timesupport is provided by using enterprise service bus (ESB) and service-oriented architecture (SOA). On-demand, efficient, flexible, and scalable smart grid power monitoringsystemcanbebuiltbythisapproach.StandardWebservices,servicefinding,serviceregistry,interfaces, and service access are implemented into a single cloud application using SOA, as the SOArelies on publishing applications as a service. Smart grid energy management can be performed usingthe ESB architecture, which includes activities such as security management, task management, andresourcemanagement, withtheimplementation ofcloud applications[24].

The Energy Service Interface (ESI) interconnects internal customer energy resources and externalsystems. Eun-Kyu Lee et al. [25] built an ESI test-bed which includes ESI, a demand response serviceserver, and customer energy resources. A demand response client module is implemented by ESI. Thecustomer energy data are represented by XML format and web service interfaces are implemented forinter-domain communications. An additional test-bed, in which the ESI is deployed on a public cloud.The two test-beds are deployed to verify that the ESI plays the service “prosumer” in a practicalmanner for a couple of energy service scenarios. The Energy Service Interface (ESI) interconnectsinternal customerenergyresources andexternalsystems.

The trend of the power grid to shift to the Smart Grid leads to the enormous pool of computing andmassivedatastoragerequirements.Toovercomethesedemandsofcloudcomputing,highlydistributed and scalable computing resources, to host the smart grid applications was proposed. Bitzerand Gebretsadik [26] discussed the feasibility of handling the monitoring of renewable energy in smartgrid on cloud computing framework by a Lab-demonstrator. The Lab-demonstration set up considersthe power system and the cloud computing domains. The distributed energy resources and the localSCADA control are considered as the power system domain whereas the cloud computing domaincontains a specific cloud computing provider [27]. Generation plants can be monitored and controlledby the local SCADA software running on the local computer. Through web-based SCADA monitoringandcontrollingofthe plants can be done fromanywhere.

JinsungByun et al. [28] proposed intelligent cloud home energy management system (iCHEMS) toaddressinefficienthomeenergymanagementsystemsduetointermittentenergygenerationbyrenewable energy. In iCHEMS, a household appliance is assigned with dynamic priority according toits type and current status. The use of household appliances is scheduled based on the assignedpriority and renewable energy capability. To enhance utilization of computing and renewable energysystem resources, iCHEMS exploits cloud computing. Energy distribution, situation-based energymanagement, and user-centric energy management are services provided by cloud resources. With thehelp of cloud computing, the proposed system reduces the high cost, requiredto implementsmartgreenhome and average totalpower consumption.

Aras Sheikhi et al. [29] proposed a model for utilizing the cloud computing technology in the smartgriddomainandexploreshowcloudcomputingplaysaneffectiveroleinDSM(DemandSideManagement) game among a group of Smart Energy Hubs (S.E.). Interaction between the utilitycompany and demand response realizing functions, the amount of loads per customer are to be reducedand at which incentive price, are performed on the cloud. In this model, to reach an optimal DSM,basedonthegametheoreticapproach,loadprofilesofS.E.HubsarecommunicatedtotheCC(Cloud Computing)whereeach S.E.Hubattemptstominimizeitsownenergy costin responseto theaggregatedinformationontheactionsoftheotherusers[30].Theresultofthegame,NashEquilibrium (NE), leads to a proper strategy for each S.E. Hub to minimize their energy bill [29]. TheDSM game reduces the PAR (Peak to average ratio) in the electricity grid and the daily energy chargesofeach S.E. Hubcan be significantlyreduced.

RajeevandAshok[31]proposedadynamicload-shiftingprogram,makesuseofreal-timedata,inacloudcomputingframeworktoaddresstheforecastingandoperationalchallengesissues,whicharetobemetwhenimplementingeffectiverenewableenergyprogram.Anewdynamicrenewablefactor,a reference parameter (captures and represents the dynamics in the pricing and shifting strategy) in thealgorithm, is proposed to facilitate on-time incentive based load shifting program. With the help ofcloud-based infrastructure, the widely distributed renewable energy sources operations are coordinatedby the utility at a minimal cost. In addition improved utilization renewable sources, reduction in thepeak demand at domestic level, additional household annual bill savings are the benefits of dynamicshiftingprogram.

Smart grids with the usage of information technologies enable efficient power grid. To cope withthe huge amount of data and daily fluctuationsby the smart meters the underlying infrastructure mustbe (i) massively scalable and (ii) elastic. Cloud computing is a cost-efficient alternative to dedicateddata centers. Martin et al. [32] explored the combination of an elastic Event Stream Processing (ESP)system named Stream Mine3G and cloud technologies in the context of energy forecasting. ESP aim atprocessing high volumestreamsofdataby processing data on-the-fly instead of storing it first.StreamMine3G, scalable and elastic ESP, is equipped with a resource manager, acquires and releasesvirtualmachines, enables loadshifting from overloadednodes to less loaded ones throughmigrationofstatefulandstatelessoperators.TheelasticitypropertiesofESPsystemwasshowcasedbyperformingseveralexperimentsondeployed StreamMine3G atAmazon EC2.

NeerajKumaretal.[33]proposedacontext-awarelayeredarchitecturefordemandsidemanagement using vehicular cyber–physical system (VCPS) with cloud support. With the integrationof vehicles with cloud computing, storage, sensing, software, platform, and Network-as-a-Service(NaaS)areofferedtotheclients.Bayesiancoalitiongameconceptandlearningautomata,anintelligent context-aware data collection and processing, are used. In this scheme, players are themobile vehicles, which can sense the SG environment and collect information from it. Alert generationand information dissemination are the actions performed by the players in the game. The player'saction probability vector is updated based on the feedback from the environment to the players.Reduction in the energy shortage and information processing delay, the increase in energy sold back tothegridare achievedin theproposed scheme.

The importance of BEMS (Building Information Management System) is increasing as Smart Gridspreads. BEMS of each entity is improved to provide high-quality services. The number of the entityincreases according to the coverage area of a building. Insung Hong et al. [34] proposed the Cloudcomputing-basedBEMStolessentheburdenofeachentitybyaSystemManager,acentralizedserver. To monitor power consumption and environmental information, sensor entities with 8-bitmicrocontroller and ZigBee and Low-cost power are used. The BEMS consists of three the PowerMonitoringEntity(PME)-monitorandcontroldevice'spowerconsumption,EnvironmentalInformation Entity (EIE) - collect environmental information, and System Manager- collect andmanage data and provide services to users. This system reduces each entity's cost and hardwarespecification.

Effective DEM depends on load and renewable production forecasting that leads to large volumesof data generated by a vast number of smart meters. In order to optimize the smart grid operations,DEMrequireshighperformancecomputing,efficientdatanetworkmanagement,robustdataanalytics,and cloud computing techniques [35]; the cloud computing model meets these requirements[36].InLiterature,approacheshavebeendevelopedtoincreasetheenergyefficiencyofHighPerformance Computing (HPC)data centers, such as the cooperation with the SG in [37], energyconsciousschedulingin[38].Mostofsmartgridapplications,suchasadvancedmetering infrastructure, SCADA, and energy management can be facilitated by the available cloud servicemodels,namelysoftwareasaservice,platformasaservice, andinfrastructureasaservice[39].

5. CloudBasedEconomicPowerDispatching

Smart grids needs to be equipped with an integrated solution to the problem of modern energy deliverynetwork thatenablestwo-wayenergyandcommunicationwiththecustomers.Tomanagelargeamounts of data, cloud computing is the best way for smart grids due to its scalable, economical, andflexible characteristics. We propose a cloud based dispatching model in the smart grid domain. Theprime responsibility of the Electric Utilities is to meet the customers' requirements at all times withquality and quantity as agreed. It matches the power generation by the utilities against the customers'power demand at all times. As the consumers' demand changes at every instant, the power generationby the Utilities should match with the consumers' demand. In reality, the power generation can't beadjusted at every instance; hence the generation is adjusted normally at 20 minutes interval. Thematchingofpowergenerationagainsttheconsumers'demandisknownasPowerDispatching(Hongseok Kim et al. [12], and Palanichamy et al. [40]). In cloud based economic power dispatchingmodel, the utility and customers interact through the cloud, and the functions for cost optimization areperformed in the cloud. From utility's perspective, cloud appears to be an information system, whichtakesaninputfromutility(e.g.,Powerdemand,weatherdata,fuelcostetc.),processestheinformation, and gives an output to utility and customers (e.g., generations of the individual plants,totalproductioncostetc.).Itisworth pointing outthattheCloudnetwork performsthepowerdispatching job as per the instruction of the Electric Utilities since the decision authority is the Utility.For its services, the Cloud gets itservice charges from the Utilities. This arrangement is economicalfortheUtilities sincetheyneednotinvest oncommunicationandcomputingfacilities.

6. Conclusion

In this survey, we provided an overview of existing works integrating cloud computing in the existingsmartgridarchitecture,inordertohaveareliableandefficientenergydistribution.Differentaspectsofenergy managementin the smart grid were discussed. We identified some important technicalissuesandproposedseveralfutureresearchdirectionsoncloud-basedsmartgrid.Usingcloudcomputing applications, energy management techniques in smart grid can be evaluated within thecloud, instead of between the end user's devices. This architecture gives more memory and storage toevaluate computing mechanism for energy management, and cost-optimization. We proposed a newhighlighton cost-effective cloud basedpowerdispatching forsmart grid applications. From thissurveyed work, we can see the integration of cloud computing in smart grid is envisioned to be usefulfor evolving the smart grid architecture further in terms of considerations such as monitoring cost,computing,and power management.

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